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FIRE IMPACTS ON WILDLIFE AND HABITAT

An Abstracted Bibliography of Pertinent Studies

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June 1975

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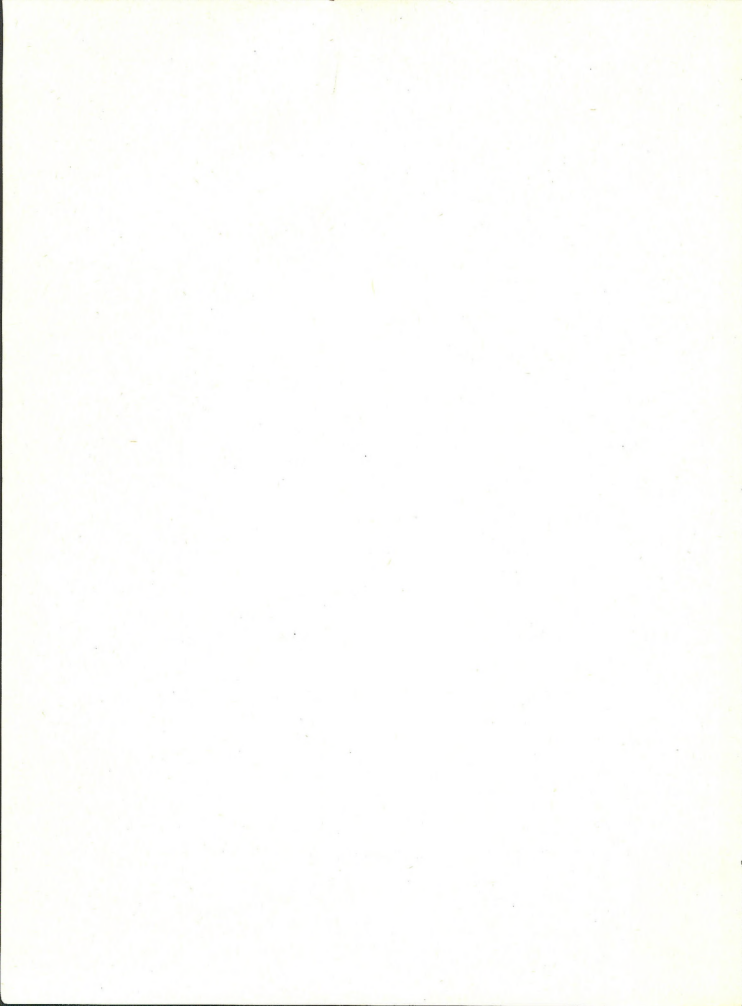
FRANK STANTON

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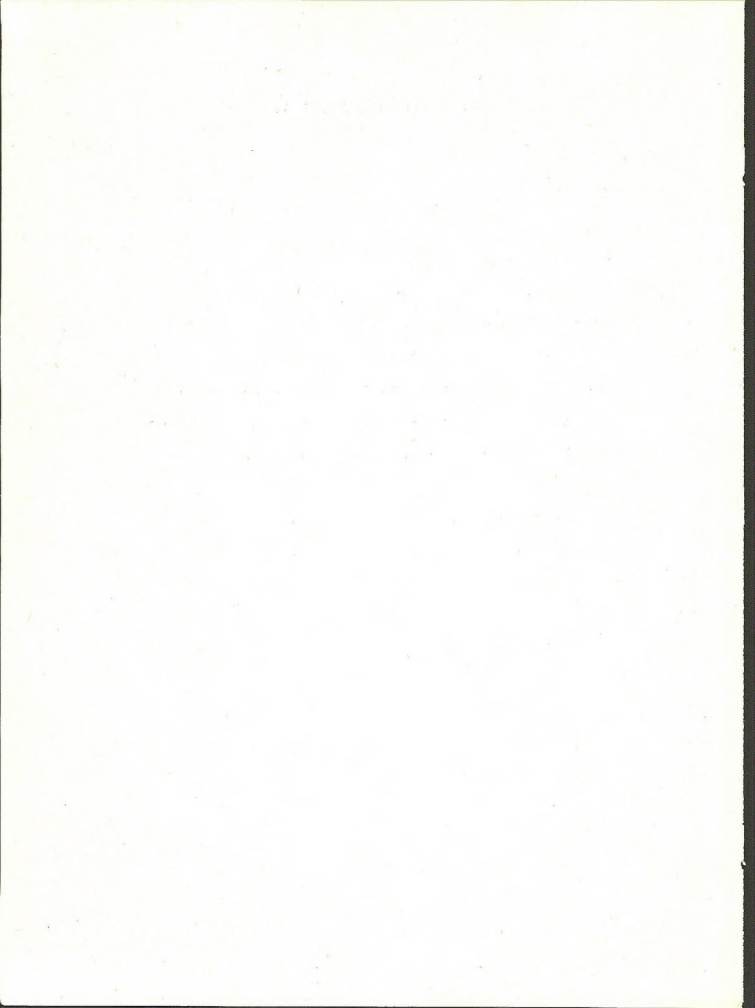


FIRE IMPACTS ON WILDLIFE AND HABITAT

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PREFACE

This release developed from library research for information needed to prepare wildlife sections of the Bureau's Fire Management Environmental Impact Statement. It is not a complete review of available literature. All abstracts are cited in the list of references. The page number of each abstract is given (in brackets) after the proper reference. The cover design and art work is by Diane Colcord, Denver Service Center.

FIRE IMPACTS ON WILDLIFE AND HABITAT

GENERAL

Rowe and Scotter (1973). Direct destruction or injury of animals is seldom an important influence on a whole population. More important are indirect effects through destruction of habitat. Faunal succession follows plant succession and there are optimum stages of plant succession for every animal species. Therefore fire exerts both short-term and long-term effects. Animals favoring early successional stages will be subject to loss of habitat for a short time following fire compared to species favoring late successional vegetation. Any influence tending toward diversifying the landscape will increase the diversity of the fauna as well as the population density of some species. By maintaining a mosaic pattern of vegetation, fire assists in the maintenance of diverse wildlife populations. The effects of wildfire are complex and must be related to the nature of the material burned, size of the area and intensity of the burn, distribution of unburned habitat types in relation to the burn, and the biology of all animals in the area. As to wildlife management, there is not enough quantitative information on the ecological effects of fire on the total environment on which to base effective management decisions. The present need is for an understanding of features and functions of ecosystems, not just on single resources.

Committee on North American Wildlife Policy (1973). Wild fires in forests and grassland can be hugely wasteful. But planned burning is essential to the maintenance of certain habitats and wildlife. Prescribed surface fires are needed to perpetuate many western conifer types.

Fires played an essential role in preserving most of our primitive grasslands. Burning usually is required to retard woody plant invasions and rejuvenate native grasses. It should be generally recognized that properly controlled burning is essential technology in managing many kinds of vegetation.

Advisory Board on Wildlife Management (1963). Of the various methods of manipulating vegetation the controlled use of fire is the most natural and much the cheapest and easiest to apply. Unfortunately, forest and chaparral areas protected for long periods may require advance treatment to reduce fuel before a creeping ground fire can be risked. Some situations, as the Isle Royale moose range, require a hot burn to open the forest canopy. Controlled burning sometimes is the only method that may have extensive application.

In successional communities it is necessary to manage the habitat to achieve or stabilize it at a desired stage. For example, fire is an essential management tool to maintain the American prairie.

Agee (1974). A National Park Service administrative policy statement (1968) says the presence or absence of natural fire within a given habitat is recognized as one of the ecological factors contributing to the perpetuation of plants and animals native to the habitat. Fires in vegetation resulting from natural causes may be allowed to run their course when such burning can be contained within predetermined units and when it will contribute to the accomplishment of approved vegetation and/or wildlife management objectives. Prescribed burning to achieve these objectives may be substituted for natural fire. One application in certain zones may be to rejuvenate winter deer range.

Agee (1974a). Much of the primitive America supported successional communities that were maintained by fire. Fire suppression has a detrimental effect on herbaceous vegetation in forest or shrub lands due to increasing competition of overstory. There are few ways to mitigate the vegetation effects from fire suppression except by using fire. Suppression of the understory forage has a detrimental effect on many species of wildlife. Without fire, vegetation trends toward uniformity, resulting in fewer wildlife species.

Komarek, R. (1963). Wild animal populations usually are mobile and may move when ecological succession destroys their habitat, but if it occurs over a wide enough area they perish. Land management for wildlife must provide measures to maintain and control vegetation patterns. Fire was at least one of the prime ecological factors responsible for the original varied mantle of vegetation.

Komarek, E.V. (1970). The action of fire in regulating insect populations is manifold and complex, depending upon the kind of fire, time of day or year, climatic and moisture conditions, wind speed, amount of fuel, moisture content of the fuel, etc. It can also be influenced by the weather conditions after the fire. The effect of fire depends on the stage in the life cycle of the insect, the degree of activity, and its ability to fly or escape the fire. Insect control by fire has long been used in agriculture, e.g., on rangeland for grasshopper control.

Oberle (1969). Some forest ecologists say that the artificial exclusion of fire has produced major changes in many forest plant communities that were dependent on fire as the chief regulator of vegetation types. Total

fire suppression has made some woods easy targets for disastrous fires. Prescribed burning was developed to manage plant communities and to reduce fire hazards. It includes slash burning, fire breaks, and burning of undergrowth and litter to reduce fire hazards.

Leopold, A. (1933). Fire is an influence operating on factors rather than directly on wildlife. The effects of fire vary with kind of game, composition of habitat, etc. Game ordinarily evades fire but may at times be entrapped or stampeded. Species with restricted home ranges may not move freely to escape fire. Even slight body burns may be fatal to game. The loss of nests and young in forest or marsh fires is a leading source of direct losses. The two peak at the same season. Fire in advance of the nesting season may remove nesting cover for the season. Nesting cover on dangerous ground (e.g., subject to flooding) can be removed by burning. Fires may concentrate nests on unburned cover. Drifting birds may appear in new areas due to dispersal caused by eviction by fire. Prairie chicken range was extended northward in the Lake States due to fire and lumbering. Controlled fire has been used to get the desired density of grass for quail nesting. Nesting cover for red grouse in Britain is maintained by controlled spot burning.

Leopold, A. S. (1950). Prior to settlement, deer seem to have occurred principally along "edges" where forest and grassland met or on recent burns in the forest. Neither dense timber nor extensive prairie supported many deer. Staple items of deer diet are characteristic of sub-climax ecological conditions (e.g., early stages in a forest successional cycle). The dense forest which cloaked so much of North America has been almost universally cut over and burned. The resultant brush fields and young stands of forest reproduction are now well stocked with deer. Logging, fire and grazing are the three principal influences which in the past have created or improved most of our present deer range. In forest areas, controlled burning might be adopted as a tool to stimulate deer food production on critical sites not adapted to timber production. Controlled burning is the cheapest tool where applicable.

Grange (1949). Whether fire is beneficial or detrimental depends upon the land use objectives. Plant species differ in fire tolerance. The role of controlled fire as a method of increasing game is always that of partial denudation for the purpose of inducing an earlier succession, or to secure certain additional benefits which arise from exposing the soil to sunlight and air. Fire is a natural method of initiating succession. Fire on game ranges is best applied on a rotation system, burning each segment at least every 20 years. Rotation burning provides desired diversity. Forest production on many plants increases following burning. Fire may reduce parasites on game ranges. It provides some immediate fertilizer effect. Some hard seeds of woody species are stimulated to germinate. In Wisconsin woods, burn patches should be from 5 to 40

acres, preferably in irregular strips. Burned marshlands attract waterfowl. Some marshes can be burned over the ice. Burn in the north from mid-March to mid-April. In the southeast, burn in February. Avoid burning cover needed in winter.

Suggestions for controlled burning

1. Determine the objectives.
2. Determine the area to be covered.
3. Choose the season carefully.
4. Have the tools and manpower for control available.
5. Choose the right weather condition by test burning.
6. Strip burn in advance around burn boundaries.
7. Watch the wind situation carefully.
8. Do not burn peat or muck when dry.

Gabrielson (1928) in Lutz (1956). Rapid running forest fires, particularly crown fires, may be very destructive to wildlife. If they occur in the nesting season of birds, the broods of the year and often the breeding stock are destroyed.

McLaughlin (1972). Spring burning is not normally a natural fire season. It may be more than normally detrimental to nesting birds and other wildlife whose young may not be able to escape from the fire area.

Anderson (1972). Studies on a Wisconsin prairie of invertebrate response to fire have shown that burning reduces the diversity and limits the number of soil arthropod individuals. Soil arthropod diversity is related to the quantity of litter and rate of decomposition. Fire reduces the amount of litter and also increases the rate of nutrient turnover; to this extent it limits soil arthropod diversity (from Lussenhop, Univ. Wisc. thesis, 1971). Organisms that occur below the soil surface are well shielded from fire because of the soil's insulating properties. During a prairie fire, surface temperatures of up to 200°C were recorded for 70 to 140 seconds. However, at depths of 0.5 and 1.0 cm in the soil, temperatures were unchanged (from Riechert and Reeder, J. Animal Ecol., 1971). Immediately following fire, predatory spiders and soil arthropods that are resistant to dessication were found to increase. However, arthropods which were unable to escape the fire by getting under the soil or other protective objects such as stones, frequently are killed by fire.

Jahn (1955). The destruction of organic matter and soil cover and the increase in pH values and CO₂ contents are usually associated with a poverty of species of soil fauna. A drought following fire may entirely suppress faunal activity.

GRASSLAND

Handley (1969). Many of the animals that live in the grasslands create conditions by their own activities that either change the vegetation or cause the effect of fire to be different. If most natural grasslands developed with fire and are at least in part perpetuated by it, then a large proportion of the mammals must be at least indirectly adapted to fire. According to Allee, et al. (1949), fire often is a disaster for mammals dwelling where fires are infrequent. Mammals living where fire is a frequent and regular occurring feature of the environment, as in grassland, survive fires because of their adaptation to them. Hot fires might overtake runners, suffocate or incinerate burrowers, burn up tree holes, and induce starvation; but the effect likely would be local. Many species depend on frequent fires for their existence.

Vogl (1967) Wisconsin. Controlled burning has been initiated to check and push back the encroaching woody vegetation, to recreate openings, and to produce vegetational conditions similar to those present in pre-settlement times. Controlled burning for grouse, deer and ducks began in 1939 and became a common management tool by the 1950s. Burning in Wisconsin has benefited sharp tail and ruffed grouse, prairie chicken, bobwhite, pheasant, turkey, woodcock, Wilson's snipe, sandhill cranes, geese and ducks, various shore birds, song birds, and birds of prey, white-tailed deer, rabbits, muskrat, and others. The burning program for waterfowl habitat creates pioneer sites for establishment of waterfowl foods, more palatable regrowth, reduction of undesirable plants and better access. Burning of sedge meadows and wet marshy areas provides excellent grazing for geese, waterfowl, deer and sandhill cranes. Burning of forested uplands adjacent to marshes increases nesting potential for some waterfowl. Larger bogs are becoming important moose habitat. Burning improves feeding, loafing and nesting habitat by increasing sedges and grasses. The early stages of wetland succession are most desirable. Transitions between types are most productive. Fire is used to reduce pole-sized hardwood stands and stimulate jack pine regeneration for deer. Fires sometimes produce undesirable results. The greatest observed loss to wildlife has been the destruction of early woodcock and mallard nests in early April. Probably most birds re-nest. Early fires also destroy nests of ruffed and prairie grouse; and sometimes kill porcupines, rabbits, mink, muskrats and mice. Fire should be used infrequently on nesting areas of prairie chickens; also, they may move booming ground locations following fire. Marshes may be converted to sterile weed-beds. The most effective fire management of wetlands is repeated surface fires, preferably while the marsh is still open. As plant succession progresses, wetlands become less productive for wildlife. If a burn is increased beyond a reasonable size, the desired effects for game may be decreased due to poorer edge distribution. Late fall burns may destroy winter cover. In general, the beneficial effects of burning far outweigh and offset any direct wildlife losses.

Ammann (1963). In Michigan, prescribed spring burning is practiced to improve sharp-tail grouse habitat. Spraying provides more control but is less selective. Spray followed by fire may be desirable, especially where conifers are present, for controlling brush.

Westemeier (1972) Illinois. Prescribed burning in August is proving to be beneficial for rejuvenating over-age grass sod. Prairie chicken nest density has increased. Burn cool season grasses (redtop and timothy) in the warm season, and warm season grasses (prairie grasses) in the cool season.

Lehmann (1965) Texas. On the Coastal Prairie, fire exclusion has not been good for Attwater's prairie chicken. Fires caused little direct mortality of adults. Prescribed burning should be done in March-April to precede nesting. Fires during the laying and hatching seasons can be destructive.

Chamrad and Dodd (1972) Texas. Prescribed burning offers strong possibilities for prairie chicken habitat manipulation in the Coastal Prairie. It appears to be a useful management tool for maintaining high quality habitat where grazing is greatly restricted or eliminated. Nesting and brooding is the most critical period. In ungrazed areas, all dates of prescribed burning improved the quality of nesting and brood habitat. Fall burning is most favorable for food production.

Kirsch and Kruse (1972) North Dakota. Without fire most native grasslands are rapidly colonized by woody species. Historically, prairie chickens were abundant on Kansas prairies where fires were frequent. In Dakota, both prairie chickens and sharp-tails became abundant after big game herds were decimated and fires were not effectively controlled. Fire suppression and the absence of deliberate use of fire to control vegetational succession has done untold damage to prairie wildlife. Preliminary results of a study revealed a similar number of nests but a greater variety of species on burned vs unburned grassland. Burning eliminated brush and produced a greater variety of plant species. Burning occurred in May. Duck nests were more numerous, as were sharp-tail broods, on the burn. Fire can be an important tool for wildlife management on prairie areas.

Tester and Marshall (1962). In northeastern Minnesota, prairie fires frequently swept the uplands; spring and fall, and helped maintain the grassland. A burning study was conducted on ten-acre plots. Spring burning was done in April; fall burning in October. Burning at either

season resulted in an advance of 10 to 20 days in development of vegetation, luxuriant new growth, an increase in forbs, and more abundant seed crops. There was no noticeable shift in species composition due to burning. Evidence is cited of woody plant invasion. Burning usually killed aspen, but willow resprouted. Populations of meadow vole (Microtus) increased with increasing litter, while the deer mouse (Peromyscus) decreased. Grasshoppers were most abundant in light or moderate amounts of litter; beetles preferred sparse litter. Prairie chickens prefer mixed vegetation of tall grass and brush. Nesting waterfowl select ponds having a medium amount of shoreline cover, rather than either bare ground or shorelines solidly filled with emergents. Pintails will nest on recent burns. Recommendations were to burn approximately one-fourth of the area each year. The best single management measure appears to be spring burning. However, nesting will be reduced the year following the burn due to lack of cover. It should then be suitable during the succeeding three years.

Wolfe (1972). Nebraska sandhills-grassland with planted pines. A large fire occurred on the plantation. White-tailed deer utilized the plantation (80 percent of the time), but few were observed on the burn (5 percent use). Mule deer used the tree plantation and grassland about equally. After the fire, mule deer made about equal use of the burned and unburned areas, deer number on the prairie declined substantially (to about 10 percent). The following year, only about 28 percent of the mule deer were using the burned plantation. Prior to the fire, a large summer population of mourning doves occupied the plantation about 60 percent of the time; after burning, about half the doves utilized the burned area. Use of the plantation, both burned and unburned, dropped substantially the year after the fire. Bobwhite quail were observed in many new areas after the fire.

Schlichtemeier (1967). Nebraska sandhills. Fire was used to restore a reed-choked marsh. It was burned in February when frozen and snowcovered. It resulted in 85 percent reduction in density of reeds and 60 percent less bulrush. It was an important waterfowl breeding and hunting area. Dense reed (Phragmites) restricts movement of young broods; desirable plants diminish. Waterfowl use increased in burned areas the same year as the fire.

Ward (1968). Manitoba. Fire is the most effective and economical tool for opening stands of tall reeds to increase area available for duck nesting at Delta marsh. Fires were a normal process and reoccurring burns performed a vital role in marsh ecology. Uncontrolled burning of nesting habitat during breeding season is destructive. Summer fires damaged roots and humus. Large scale autumn burning may be detrimental through

loss of vegetation to catch and hold drifting snow. Spring fires are used before nesting season to remove old growth without affecting regrowth; summer fires are prescribed after nesting. Spring burning creates more edge for nesting and eliminates woody plants. Summer fires create lasting changes in plant composition. Both ducks and muskrats increased following fires. Unless the large marshes of Manitoba, managed for waterfowl, include use of fire they will deteriorate and may even cease to be marshes.

Heady (1972) California. Changes in percentage species composition of plants and animals in the annual grassland for a year or more are the most striking effects of burning. There is an immediate reduction in rodent numbers following fire, but a few of all species survive. Lawrence (1966) and Cook (1959) found rodent numbers recovered within three years.

TAIGA - TUNDRA

Lutz (1956). Alaska has been subject, through historic time, to extensive and repeated fires. Dry forests and the lichen-moss-shrub ground cover readily carry fire. Climax white spruce on the better drained sites have been replaced with paper birch and quaking aspen. Revegetation usually is prompt. Spruce becomes prominent in the birch understory in about 80 years and becomes dominant in 100 to 200 years. Aspen sprouts and seedlings often come in abundantly, but are replaced by white spruce in about 60 years. Repeated severe fires in white spruce stands may result in treeless herb or shrub communities requiring 100-200 years for natural reconversion. Black spruce, occupying low, wet sites, usually regenerates to a pure stand even following an intense fire. Organic matter tends to remain unincorporated. It may become a foot thick under old stands. Earthworms are scarce. Permafrost is 12 to 18 inches below the surface. Even severe fires may not expose much mineral soil.

In general, fur-bearing animals appear to be adversely affected by most severe fires. Small mammals, many of which serve as food for fur-bearers, are killed when their habitat burns. The marten may be most vulnerable. Large fires destroy many fox, fisher, ermine and lynx. The finest furs come from the most densely wooded districts. Recurrent fires were considered a threat to the old fur trade. The effect of uncontrolled fires on moose is not clear. In certain areas the moose population has increased following fire. However, there are extensive areas which have burned repeatedly and which support much browse but few moose. Also, moose are moving into unburned areas. The possibilities of prescribed burning for moose habitat are recognized. The effects of fire on caribou are generally agreed to be harmful or even disastrous. Whereas the moose prefers vegetation in early stages of succession, the barren ground caribou normally lives in climax plant communities. Fruticose lichens and certain beard lichens growing on trees, form the principal winter food of the caribou. These lichens are highly flammable and recovery is excessively slow. Recovery in usual situations will take 40 to 50 years. Full recovery of tall-growth lichens may require more than 100 years. Extensive fires have destroyed large portions of caribou range. Burned areas are avoided by caribou. Recurring fires that break up their range into small tracts adversely affect caribou.

Oberle (1969) Alaska. Fire has been an important part of the ecology of the interior. When fire is excluded from many lowland sites, an insulating carpet of moss tends to accumulate and raise the permafrost level. Permafrost close to the surface favors black spruce and these areas are veritable deserts. Bear, deer, moose, and other animals depend on lightning fires to maintain a constant cycle of vegetation types for food and cover. Other biologists at the University of Alaska have criticized the fire-fighting crusade - particularly in interior Alaska where the permafrost and short growing season produce timber of minimal market value far from any road or settlement. The bulldozers used in carving fire lines around interior fires may cause more erosion than the fires themselves.

Buckley (1956) Alaska. The effects of fire on wildlife are direct and indirect. The direct destruction of animals would be principally in the spring on nests and young of birds and mammals. These losses are temporary provided there is a source of reinvasion and provided the habitats have not changed significantly. The indirect effects on habitat are far more important and may last for decades, or may be irreversible. Fire may be responsible for decreased water levels due to denuded surface effect on lowering permafrost table - this may be the most significant and far-reaching effect of fire on wildlife. The present patchwork of vegetation types provides much desirable edge. Relatively few wildlife species depend upon climax vegetation. The caribou is the best example - they can survive without lichens, however, they regularly prefer them. Lichens do not recover from fire for 30-40 years or more. Immediately following fire there is little to attract any wildlife species. By the third or fourth year sub-climax communities provide browse from sprouts, etc. The effect of lowered water levels reduces the area available to waterfowl. But removal of woody vegetation as by fire increases the attractiveness of areas to waterfowl. Also, new vegetation appears earlier and provides early nesting sites. Early nests are most successful where growing seasons are short.

Leopold and Darling (1953) Alaska. The mere passage of fire through timberland does not necessarily create optimum conditions for moose. Fire may produce grassland, spruce, etc. with little birch or willow. Aspen sprouts do not withstand heavy browsing. Years may pass before appreciable amounts of browse come in following fire.

Leopold and Darling (1953a) Alaska. Moose achieves highest density in forest areas where winter ranges have been opened by fire or any other form of timber removal, permitting regeneration of willow, birch or aspen - characteristic of secondary stages of forest succession. The moose is primarily an animal of a sub-climax biota. Conversely, the caribou seems to require a winter range supplied with lichens which are part of the climax flora of forest borders. The caribou is a member of a climax flora. Accelerated burning has influenced moose favorably and caribou unfavorably over a large part of Alaska south of the Arctic Circle. The controlled use of fire to improve critical areas of winter range in central and southern Alaska would be advantageous and, in some localities, quite practicable. Moose range can be destroyed by a burn as readily as it can be created. Such intensive management is most desirable near population centers. Caribou numbers probably will continue to diminish - particularly in central and southern Alaska. The remaining lichen ranges must be protected from fire if caribou are to survive. The controlled use or exclusion of fire should be part of an integrated plan of game management.

Spencer and Chatelain (1953). A large burn in 1947 on the Kenai Peninsula induced an increase in moose population of about four hundred percent between 1950 and 1953 - almost entirely due to aspen sucker growth. On some ranges forest succession advances faster than moose populations can build up to utilize the forage. All the important moose ranges in southern Alaska are the result of some disrupting influence that removed the original forest cover and allowed young second-growth browse species to become abundant. The most important of these influences has been fire. (Beaver activity is another influence.) The possibility of controlled burning is being investigated as a means of creating and preserving winter ranges. Present fire control programs are so effective in these areas that more moose range is being lost through forest succession than is being created. Controlled burning can partially alleviate the winter range problem but cannot completely remedy it.

Spencer and Hakala (1964). In 1947 a 310,000 acre wildfire burned approximately one-fourth of the moose winter habitat on the Kenai National Moose Range. Historically this was stone caribou country but they were extirpated early in this century. Earlier, widespread fires created habitat favorable to moose and a growing herd developed coincidental to disappearance of caribou. The current (1964) peak population is largely supported by forage in the 1947 burn. Important winter forage species are willow, birch, serviceberry, mountain ash, and viburnum. A high level of forage began about 8 or 9 years after the fire and has continued high for 8 years. The loss of the forage value of hardwood browse will occur some 30 to 35 years following fire. The burn is a favored calving ground with some preference for the muskeg or marshy areas. The moose population moves from the mountains into the wintering area early in December. Concentrations occur only during severe winter, at which time there may be 5 moose per square mile. Three years after the fire, 15 percent of the herd wintered in the burn. Ten to twelve years after, 55 to 60 percent wintered there. Calf ratios approximately doubled in 10 to 12 years. A timely reburn to reduce spruce reproduction may extend the period of browse production. However, repeated burns may favor grasses and forbs, and eliminate browse.

Viereck (1973). There are many published reports on the detrimental effects of fire on caribou habitat in Alaska. These statements, mainly from Canada, were largely based on the caribou's heavy dependence on lichens. Skoog (1968) believed that in Alaska the irregular terrain and the interspersed of natural fire barriers permits many areas of good habitat to escape destruction by fire. Caribou stomach content analysis indicates less dependence on lichens in Alaska. Examination of over 500 rumina by Skoog showed a fall diet comprised of 50 percent sedge-grass, and 30 percent lichens. During the winter, utilization of these foods

is estimated to be equal. Skoog concluded that, in the area studied, caribou can utilize the extensive sedge forage on the tundra, alpine meadows, bogs and lake shores, and this greatly mitigates the losses due to fire. Leopold and Darling (1953) stated that up to 50 or even 100 years are required for lichens to achieve preburn levels of production. Scotter (1971), in Canada, found that when mature spruce-lichen forests are burned, major forage lichens usually take 70 to 100 years or more to fully recover. Various studies showed that fire improved habitat for moose, and they achieve highest densities in forest areas opened up to permit browse regeneration. Wild sheep and goats occupy range not generally subject to fire; however, some burned forest land converted to grass has improved sheep range. Following the large Kenai fire, the population of voles was about equal inside and outside the burn during the next year. Numbers of shrews probably were reduced. Fur bearers must move to new areas following fire. The best pelts are from unburned areas. The short-term effect on a beaver colony is destruction of the food supply; but over a long term the food supply is increased. Fire control contributes to the reduction of beaver habitat. Edwards (1954), working in British Columbia, concluded that fire removed marten for decades and found that decline in caribou restricted the use of forested lowlands by wolverine and grizzly bear. Likewise in eastern Canada, fisher and marten were practically absent from extensive, recently logged or burned areas. Spruce grouse brood production was reduced approximately in half the year after a fire, compared with the same area just before the fire. A number of insect species often are prevalent in fire-damaged trees. Changes in plant composition after fire are accompanied by changes in insect fauna.

Keith and Surrendi (1971). A spring wildfire on a square-mile study area in central Alberta caused snowshoe hares to abandon severely burned sites. Adult hares moved to less intensively burned areas. The proportion of juveniles on the burn was reduced markedly during the first summer. It was believed they moved to unburned habitat within one-half mile. There was no evidence of direct mortality. The abandonment and reoccupation of severely burned areas were clearly related to cover changes caused by the fire and subsequent revegetation. Food was also scarce on the burn during the first two months after the fire. Hares returned to the severe burn during the second summer following the fire, as brushy cover redeveloped through sprouting - principally aspen and poplar.

Doerr, et al. (1970) in Alberta reported that fire, a recurrent natural phenomenon, significantly influences animal populations. A spring wild-fire on a four-square-mile study area resulted in a spectacular increase in aspen from sprouts. Grouse were little affected in distribution or in their use of drumming logs. About half the birds moved out of the burn for about one year. There was nearly complete nesting failure due to destruction of nests by fire. Nesting returned to normal the next year. The number of drumming males was reduced for two years following the fire.

Requa (1964). In the Yukon, moose follow burned-over areas to new browse. Migratory birds nest in "fire type" vegetation and raise broods there. Herbivores are sustained by the fire type accompanied with predators. Migratory birds and certain other species favor specific phases of the cycle from fresh burn to stands of mature timber.

Scotter (1964). Effects of fire on wildlife are both direct and indirect. In black spruce forests of Saskatchewan, caribou prefer older forests, whereas moose prefer younger stands. The tangle of fallen snags on recent burns probably impedes movement. Black bears frequented burns to obtain berries. Red squirrels generally were found only in forests older than 50 years. Fire apparently destroyed marten habitat. The snowshoe hare benefited from post-fire vegetation. Invasion of quaking aspen following fire benefited beavers. Sharp-tailed grouse increased. Spruce grouse were confined to mature black spruce. Slate-colored junco and white-crowned sparrows occupied black spruce or spruce-birch forest. Lichens preferred by caribou were found infrequently in forests less than 30 years old. In the study area, forest fires have been one of the principal causes in the decline of caribou populations. Caribou winter range is restricted largely to the coniferous forest belt. Browse is of limited importance in their winter diet. Deciduous shrubs other than willow have limited value as forage. Lichens make up about 50 percent of the caribou's winter food. Annual growth rates of two favored species (Cladonia) were approximately 4 and 5 mm.

Scotter (1967). Caribou movements may be deflected by recent burns. Lichens generally are regarded as the principal winter food of caribou. In northern Canada this amounted to about 60 percent of the diet. Lichen production increased from 3 lbs/acre air-dried in stands under 10 yrs. old, to 725 lbs. in stands over 120 yrs. old. It usually takes from 70 yrs. to more than a century for the major forage lichens to recover to their former abundance and composition. Their average growth rate ranged from 3 to 5 mm/yr. depending on species. Arboreal lichens may be an important food source for caribou, particularly as emergency food during periods of deep or ice-crusted snow. Caribou, unlike moose, prefer habitats more than 50 years of age.

Forest fires have been one of the principal causes of the decline of caribou numbers. More prevention and control of forest fires would seem desirable.

Scotter (1970). Destruction of habitat by fire in the taiga might limit the range of barren-ground caribou in winter; however, fires are rare on the summer range in northern Canadian tundra and barren grounds. Caribou prefer older-age class forest. Fires at the southern limits of winter range sometimes are beneficial in improving production of lichens and other forage plants in the more closed forest stands. Muskeg fires destroying Sphagnum spp. may result in replacement by better forage species. It has been suggested that fire in black spruce forests, sphagnum peat lands, treeless bogs, or wooded muskegs, could increase the lichen supply. Fire may beneficially affect nutrient cycling, increase summer soil temperatures, remove excessive humus layers, and increase browse supply for moose. The vast flat stretches of northern Canada are not comparable to the rough Alaska terrain. Food preferences of caribou are largely met in climax plant communities. These caribou are the only native ungulate in the region adapted to using the lichen-rich components of the taiga. Caribou avoid young forests. Snow conditions, low forage production and wind-fallen trees make recent burns unattractive to caribou.

Banfield (1949). In parts of northeastern Canada, large forest fires during the latter part of the last century have been blamed for the caribou population decrease. On excellent condition winter range bordering the barren grounds there were no signs of fires.

Grange (1965). The abundance of many northern forest animals is related to the length of time since the habitat burned. The snowshoe rabbit cycle, with high populations lasting two to five years, averages about once in ten years. This orderly progression of events springs from the habits and adaptations of animals and of vegetation under the environmental circumstances altered or set in motion by the initiating force - which generally is fire. Snowshoe rabbit population explosions are limited to very early succession forest stages not long after the occurrence of fire. A reservoir of breeding stock carries over in older forests, but rabbits become abundant only when there are large acreages of new forest reproduction. Other agencies of disturbance, often of small size, explain the survival of small populations. Virtually all plant species important to snowshoe rabbits show pronounced adjustment to fire: jackpine, lodgepole pine, black spruce, quaking aspen, white cedar, tamarack, birch, willow, etc. When an appropriate point of food and shelter deterioration arrives, the rabbit population crash occurs. Immediate causes may be disease, starvation, climatic factors, etc. The role of fire must be taken into account in order to understand the ecology of the snowshoe rabbit country.

Other species related to this cyclic effect include lynx and various grouse species. It is important that northern animal cycles be seen in the context of changing habitat condition.

Allen (1974). On Isle Royale in Lake Superior, one-quarter of the timberlands burned in 1936. The new growth of aspen, birch, willow, and other favored moose browse plants proliferated on thousands of acres. The moose responded with increasing numbers into the 1940s. This period was followed by overutilization of browse and increasing moose mortality.

Patric and Webb (1953) New York. Present high beaver populations of many areas are the direct result of the extensive clearcutting of timber and the widespread forest fires which were characteristic in the northern forests until recent years. Modern forest fire control and intensive forest management practices are gradually reducing the areas of suitable beaver habitat. The beaver is adapted to the early stages of forest succession, especially the post-fire types which include aspen and willow. The beaver will be eliminated from many areas when the forest is maintained in climax vegetation.

CONIFER FOREST - MONTANE

Leege (1969). In northern Idaho mixed-conifer forest the most abundant food shrubs for deer and elk are: willow (*S. scouleriana*), serviceberry (*A. alnifolia*), mountain maple (*A. glabrum*) and redstem ceanothus (*C. sanguineus*). Prescribed burning trials indicated that both spring and fall burning were feasible and produced desirable results. Large wild fires early in the century created extensive browse ranges and big game animals have thrived. Important shrubs, like redstem ceanothus, are now being shaded and dying out. Prescribed burning trials have shown that fall burning more completely consumed the litter and exposed bare soil causing greater erosion potential. Willow, mountain maple, serviceberry and ocean spray (*H. discolor*) sprouted most prolifically, producing as many as 120 sprouts per plant. Less active (about 15 to 50 sprouts per plant) were redstem ceanothus, bitter cherry (*P. emarginata*), cascara (*R. purshiana*) and syringa (*P. lewisii*). Willow made the best growth after one season, averaging 3-5 feet in height. Fall burned plants produced fewer sprouts but growth was greater. Number of sprouts is more important than length. After three growing seasons, most of the principal species had grown beyond reach (willow, serviceberry, maple). Big game preferred eating the new growth on the burned area rather than on unburned areas regardless of species or season burned. Spring burning produced sprouts for the following winter, fall burning produced one year later. Normally unpalatable shrubs like ocean spray, syringa and bitter cherry were much better utilized after burning. Elk also browsed larger twigs. These effects, on spring burns, continued through two winters. Protein content was consistently higher on burned-area shrubs; effects lasted at least through two winter seasons. Redstem and bitter cherry seedlings were numerous on burns. Spring burning produced 60,000 redstem seedlings per acre; fall burning gave 242,000. The average cost of burning 4,000 acres on three forests was 71 cents per acre.

Leege (1968). Controlled burning is feasible in early spring after snow melt at lower elevations, and in the fall soon after seasonal rains begin. Key game winter ranges are scheduled to be burned on a rotation to keep maximum production of browse.

Lyon (1966). Prescribed fires, particularly in logging slash, are not unusual in forests of northern Idaho. Natural vegetation recovers rapidly. Following an August burn on logged Douglas-fir site, sprouting from shrubs doubled pre-fire density in two years. Maple recovered eight percent of pre-fire volume; willow 42 percent. Mountain ash was eliminated. Snowbrush produced many new seedlings. Elderberry resprouted and became third in shrub volume in two years. Serviceberry and snowberry lost volume between the first and second post burn years. Irreversible patterns are

set during the first two postburn years. Forage values for big game at least doubled within two years. Willow became most abundant and was all available, mountain maple was second; both will grow out of reach in a few years. Snowbrush, and other low shrubs with forage value, came in. Snowbrush could disappear in 20 years under a tree canopy. The wildlife habitat values will peak in the first 15 years and then decline. The stand should resemble preburn condition in 40 years.

Lyon (1969) Idaho. Wildlife populations fluctuate with vegetation changes, especially big game. Recovery of burned forest coincided with game population reductions.

University of Idaho (1973). This report is on the effects of prescribed burning on four browse species: mountain maple, serviceberry, redstem ceanothus and willow. Crude protein was significantly higher the first year after spring burning in 83 percent of the burned vs unburned comparisons, although it was lower in redstem. Fat content was generally lower the first year but higher the second and third years after burning for all species: willow was highest, redstem lowest. Crude fiber was significantly lowered in 72 percent of the comparisons for all years; however it increased in mountain maple. Production of available redstem on the Lochsa watershed burned sites exceeded the control after two years; but on the St. Joe production was lower, due primarily to heavy summer use. Utilization data showed higher summer and winter use by big game of burned compared to nonburned areas, and a higher preference for redstem than the other browse species. It was recommended that burning be done on scattered areas on a given tract of winter range rather than burning one large acreage on the premise that animal distribution and plant use may be more uniform.

Gartner and Thompson (1972). In the Black Hills of South Dakota under exclusion of natural fires, woody plants increase and often become dominant. Controlled burning results in more productive grasslands with maximum diversity, more productive forests with a more diverse understory, better wildlife habitat, increased water production, decreased cost of wildfire protection and aesthetic enhancement. Controlled burning is manageable in the spring and should be usable in fall and winter depending on weather, and soil and fuel moisture. Controlled spring burning in bluestem grasslands for reducing invading pine seedlings is practical and will not reduce forage production. Controlled fires are being used in the Black Hills to improve big game range.

Biswell (1963) California. Light controlled burning in ponderosa pine constituted no hazard in the development of tree-killing insects. Rodent trapping resulted in not a single mouse caught in areas of pine cleaned by prescribed burning. Fire may create conditions unfavorable to rodents.

Biswell (1972) California. Following burning in ponderosa pine-grass type, resprouting shrubs were more tender and available for browse. More sunshine reaching the understory improves palatability and nutrients. Fire is an effective tool in controlling shrubs in the pine understory. It might remove non-sprouting shrubs and reduce sprouters. If more shrubs is the objective, they should be established in openings. It may take several fires to deplete the supply of seeds in the ground. For highly desirable shrubs, as bitterbrush, any fire should be used in the fall after the seeds have been cached where they will be protected.

Kilgore (1971) California. A prescribed burn in the red fir type in King's Canyon National Park resulted in no noticeable change in deer or bird numbers. Fire suppression seems to be of questionable value in this type unless there is danger to human life or property. It would seem to be desirable to allow most lightning fires in red fir forests to burn without suppression.

Yeager (1950). Where forest stands are destroyed by fire, cover habitat for marten may be lost for many years. Mice and other small mammals, and birds may be abundant on burns. Where burns are bordered by spruce-fir, they undoubtedly provide excellent foraging grounds.

Lawrence and Biswell (1972). In California's Sierra Nevada giant-sequoia forest, management has created open, park-like conditions. In the primitive forests, frequent surface fires caused by lightning prevented destruction by holocaust. Studies on four 20-acre plots included cutting, piling and burning small trees, underbrush and debris. Cutting and burning increased rate of seedling growth and produced new crown sprouts. Utilization by deer seemed to increase with growth rate. Treatment favored increase in plant sugar content. Shrubs were not abundant on untreated areas because of absence of fires. Shrub hard-seeds failed to germinate. The number of shrubs increased on the lightly burned areas. Fire suppression for over 70 years resulted in accumulated forest debris and increased canopy density and simultaneously diminished the quality of wild-life habitat and increased the fire hazards. Treatment improved conditions for deer. Accessibility of forage plants improved.

Moore (1974). As the plant community goes so goes the animal kingdom. Moose, elk, deer, bear, grouse, marten, lynx and other forest creatures thrive, remain static, or die depending on the plant-food chain conditions. For them ecosystem diversity is literally the essence of life. Fire is the agent whose raw force has in the past perpetuated vegetative and wildlife variety.

Gordon (1954) New Mexico. In June and July, 1951, two large forest fires apparently had extremely detrimental initial effects on young turkeys and deer fawns. Game animals moved back into the burned areas during the following spring when weeds and some browse made good new growth (aspen, locust, oak). The food and cover were favorable for turkeys and deer, and their populations increased during 1952 and 1953. Studies indicate that, in general, the habitat has been improved and that the fires have benefited wildlife after the initial detrimental effect by opening up dense stands of timber and thus allowing a dense ground cover and more abundant food supply. Grass seeding in the burns was recommended.

Mutch (1974). Many plants and animals are adapted to the cyclic occurrence of wildland fires. Different patterns of fire intensities, controlled by differences in fuels, weather, and topography, produce a mosaic of habitats that ensures community diversity. Following an August-September fire in the Selway Wilderness ponderosa type, most shrubs were resprouting 2-3 weeks after the fire - willows were up 1 foot high. Grasses grew 2-3 inches. Deer, elk or bear were observed within the fire perimeter during the fire period. Many grouse were in the burn daily, even while it was smoky; some apparently were feeding on grass seed in the ashes.

Hatter (1949). In British Columbia increases in moose population have occurred in regions burned over during the early days of land settlement and railway construction.

Edwards (1954). The mountain caribou has decreased alarmingly throughout most of British Columbia. Fire has drastically changed the vegetation of the valleys. Fire destroyed the forest, and made new and extensive range for a number of species. It totally removed the marten for decades; it restricted the wolverine and grizzly bear. Mule deer increased abundantly. Cougars became common. Coyotes flourished where deer mice and Columbia ground squirrels were abundant. Beaver increased; also black bears. Moose expanded ranges into burned areas followed by wolves. Caribou moved seasonally from high meadows and open forests to lowland mature forests interspersed with bogs and ponds where lichens and browse are the chief forage. Fires reduced mature lowland forests by 60-70 percent. Caribou decline occurred following destruction of forests used as winter range (1930s). Small areas of climax vegetation are necessary for survival of the caribou (from 3 to 10 percent of its total annual range). Protection of existing remnants of lowland forests from fire is necessary for survival of the caribou.

CONIFER FOREST - NORTH COASTAL

Redfield et al. (1970) British Columbia. Grouse density was as high on logged and slash-burned areas as on burns. However, a large wildfire was followed by a spectacular decline in grouse populations. Large fires and a subsequent set back in plant succession are not sufficient to maintain densities of grouse. Clearcut logging, with or without slash burning, stimulated increases in grouse populations. The long-term effects of repeated burning in Pacific Coast regions may be harmful to the ecosystem. Fire is not a necessary prerequisite for high densities of blue grouse, nor can it prevent a decline. Time of burning and temperature may affect the release of nutrients differently. Fire may change the quality of plants on an area, the gross structure of the vegetation, the successional pattern, the microclimate, and alter other components of the ecosystem, including the animals living there. Blue grouse move from coniferous forest winter range to more open areas for the breeding season. Normally low populations increase rapidly following logging or burning. Effects last 10 to 25 years until the canopy closes. Hens with older broods seem to select burned areas. Populations of some species of wildlife increase following burning; probably due to opening the habitat or to setting back succession. Burning may not be bad for blue grouse populations in the short-term view, but other methods of opening up the habitat may be better over the long-term.

Black and Hooven (1974). In the Pacific Northwest, more than twice as many plant species occurred on a clearcut and slash burned Douglas-fir site as were found in a mature forest. After the 43,000 acre Oxbow Burn of 1966 in western Oregon, a study was initiated to determine the impact of the fire on small mammal communities. Plant succession progressed rapidly with forbs and bracken fern giving way to shrub dominance by 1973, seven years after the fire. Small mammal populations were decimated by the fire. Within one year, deer mice were much more numerous on burned areas than on unburned areas, but other species were absent or scarce. Shrews and voles which were abundant on unburned areas apparently were destroyed by the fire or were unable to survive after habitat destruction. Within two years large increases occurred in abundance of Oregon and long-tailed voles, and a few shrews were first recorded. Trowbridge's and vagrant shrews and Oregon voles continued to increase each year. Long-tailed voles had disappeared completely on burned areas by 1971; they were never trapped on unburned, control areas. In 1973, western red-backed voles were first taken on the unburned area in Douglas-fir regeneration. Populations of deer mice declined sharply and a decline in total numbers of small mammals occurred on burned areas in 1970. Thereafter, size and relative species composition of small mammal communities was nearly comparable on burned and unburned areas. However, seven years after the fire, chipmunks seldom were found on the burn.

In another study, in the western Oregon Cascades, small mammal populations were compared on clearcut-slash burned areas and uncut stands of 125-year-old Douglas-fir. Twice as many plant species were present four years after logging. Half as many shrews were caught on burned clearcuttings as on uncut forest; but deer mice and voles increased. Chipmunks were more abundant in the forest. Occurring in the forest but rare in clearcut were snowshoe hare, red-backed vole, flying squirrel, and pine squirrel.

Isaac (1963). Young Douglas-fir stands which follow fire are singularly free from insects and disease. Bird and animal life thrives in openings in forests and use the dense forest only for cover and protection. A dense continuous forest of Douglas-fir is almost a biological desert. The great Tillamook (Oregon) forest fire wiped out the dry-land snail which is an intermediate host for certain liver fluke and lungworms in deer.

Wright and Bollen (1961) Oregon. Microflora of a Douglas-fir forest were much reduced immediately after burning and did not approach normal for 14 months.

WOODLAND
California Chaparral

Dasmann et al. (1967). Bulldozed lanes on ridgetops, parallel contours, etc. for fuel breaks, access for fire fighters, etc., also provide access for deer and improve nutritive value of forage. Deer use increased ten times. Some 14-year-old jobs are still functioning. Prescribed burning, preferably after crushing the brush with bulldozers, is also done to open stands. When burned for deer habitat improvement, areas should be small or at least discontinuous. Cover patches of 40 acres or more are necessary. No point should be more than 100 yards to cover. Burning with crushing has cost approximately \$30 per acre. Wildfire rehab usually consists of aerial seeding to grass and spraying with herbicide to control brush sprouts. Rehab provides opportunities for considering wildlife. Studies on Cow Mountain showed that fawn production and total population of deer increased markedly on treated areas.

Longhurst (1969). Brush burning trials were carried out in northern California (Cow Mountain) chaparral to determine effects on deer. Widely distributed burned spots averaged about 50 acres in size. The amount of burning should be kept in balance with utilization. Good distribution of unburned escape cover is essential to achieve good distribution of use in burns. Brush was crushed several months before burning. Burning occurred in May and June. North slopes supporting heavy live oak brush could be burned only during high risk conditions. South facing slopes of chamise could be burned at any dry season. Crushing before burning prevented thickets of blackened stubs which limit deer movement. The fires were not a direct hazard to deer on the small areas burned. Mature, unburned brush provides good cover but poor quality of forage. The shrub regrowth from seedlings and crown sprouts produces higher protein content over about a three-year period. Burning does not favor acorn production. By leaving unburned patches, deer use them for cover and acorns (may amount to one-half the late summer diet). A major benefit of burning for deer management results from increased accessibility of deer to hunters.

Biswell (1961). Some mortality occurs when sprouts of deerbrush are heavily browsed during the first growing season after burning. Burning of brushfields in the fall appeared to produce more seedlings than spring burning. Burning after April 1 delayed seed germination until the following spring.

Biswell (1969). Prescribed burning can be a useful tool in the manipulation of brushlands for wildlife. Some shrubs put out crown sprouts after fire; others reproduce only from seed. A prescription must be prepared for each area to be burned. An associated benefit to burning is the improved access for hunting. Controlled burning under permit was authorized in California in 1945. Some prescribed burning, mainly in chamise

chaparral, has been done exclusively for wildlife. Studies here showed that where dense brush had been opened by scattered, small burned patches, deer density was approximately three times greater than in untreated brush even after 5 and 6 years. On an intense wildfire burn, deer density rose 400 percent by the next summer, but rapidly declined. The wildfire burn was expected to reach the same status as the heavy untreated brush in 12 to 15 years. The forage in the opened-brush burns was of higher quality and deer maintained winter weights better than on untreated areas. The management objective apparently should be to reduce the brush cover in spots and introduce palatable, herbaceous species for use in winter and early spring. This results in desirable interspersion of food and cover. Management should maintain productivity over a long period.

Reynolds and Sampson (1943). Succulent crown sprouts have higher nutritive values than older, uncropped growth stages. Repeated close browsing retards development of shrubs toward maturity. If excessive, however, plants may die. The higher moisture content of sprouts would favor their summer use by deer. Suggested management for deer is to burn or slash areas every two or three years on selected stands of chaparral. Manage to produce crown sprouts.

Cowles (1967). Extensive suppression of fire in much of southern California chaparral areas might have caused serious stresses in the lives of its native fauna possibly including a food deficiency for the condor. Extensive fire suppression with extreme changes in vegetation and the associated faunistic consequences may have adversely affected condors. There may be a calcium deficiency due to changing diet to larger animals. Condors are hampered or excluded from tall, dense vegetation as chaparral; small mammals are not plentiful and are difficult to get. Lack of large openings results in difficulties of gaining flight.

Miller (1963). In California chaparral, about 50 percent of the area should be left in brush for wildlife cover. Small burns are beneficial; they should be in balance with herd populations. Removal of chaparral from steep slopes is not recommended.

Doman (1967). The concept of "worthless brush" applied to this chaparral cover is fallacious and dangerous, particular in relation to wildlife habitat, watershed protection, and environmental control.

Howard, et al. (1959). A study was conducted in California to learn how destructive control brush burning is to small animals. The principal vegetation was annual grasses and forbs, ceanothus, live oaks and digger pine. Caged animals placed within the fire area were: rattlesnakes, ground squirrels, white-footed mice and laboratory rats. Cages placed beneath logs or dead brush reached lethal temperatures even when buried 6 inches deep. Animals in rock outcrops survived as long as shielded from radiant heat and as long as the crevice did not serve as a chimney to adjacent burning vegetation. The lethal temperature for the rodents seems to be between 138-145°F. The rattlesnakes, placed in rock crevices, survived. A second procedure was to count animals coming to a spring. Increased use occurred the day after the fire (valley quail, small birds, cottontails, and gray squirrels). Few, if any, adult birds of any kind were killed by the fire. The authors reported numerous observations of birds and mammals in the fire area during the fire. None of the three observers saw animals that had been singed or burned by fire. Animals displayed amazing calmness and all managed to avoid hot spots. It was concluded that most range fires are not directly destructive to wildlife. Once an area has been burned, however, population densities may markedly change because of alteration in habitat conditions. In general, the opening up of dense stands of brush benefits most wildlife species. Birds, rodents and cottontail rabbits frequently make trails, removing forage, from around woody vegetation, and these become natural fire-breaks protecting stands of woody vegetation.

Lawrence (1966). In California, no species is totally eliminated following a chaparral fire, nor is there any apparent diminution of total life on a burn after plant growth resumes. The woodrat, due to its tree nests, was perhaps the most vulnerable species present. In the bare ash following the fire many species were severely exposed to predation, and populations of most small mammals and some brush-dwelling birds decreased rapidly. Predatory birds and mammals increased, as did some seed-eating birds that found good foraging on the exposed earth. Birds and mammals that normally exhibit a strong preference for chaparral habitat were substantially reduced in numbers in the years following the burn. Conversely, some birds preferring grassland on oak-woodland increased in number. The fire resulted in an overall increase in densities of nesting birds. None of the small mammals increased in numbers but some of the larger predators, such as the coyote and badger, moved into the burn during the months following the fire. Temperature measurements indicate that animals probably experience no ill effects of the fire heat if they occupy a burrow system of at least 3 inches in depth. Suffocation is a greater danger; fire temperatures raise vapor pressure. Mammals evaporate water vapor to lower body temperature, however, there is a lethal limit. At the lower limits of 22 percent relative humidity, the lethal temperatures range from 138°F to 145°F. The tolerance drops to 120°F when the relative humidity is above 60 percent. One immediate effect of the fire was a large increase in numbers of predators - particularly hawks and owls.

Cook (1959). A 600-acre area of grassland and brush near Berkeley burned by an October wildfire. Both the grass and brush covered areas burned completely leaving practically no cover. Annual grasses dominated the grassland during the second and third years following the fire. On the brush habitat which had been Baccharis, Rhus and Artemisia species interspersed with grasses, no cover remained. Annual grasses and weeds came in along with some shrubs the second and third years. Small mammals were trapped on the two habitats, both on the burn and on adjacent control areas. After an initial extermination of mice on the burn, lack of cover apparently restricted size of rodent populations. Food was abundant by the spring following fire. Microtus apparently needed at least one year's accumulation of litter to afford cover. Conditions reached an optimum the second year for Reithrodontomys in the grassland. Peromyscus, also a seed eater, remained at low population levels - probably due to restricted home ranges. The many seed producing annuals occurring after the fire especially benefited Reithrodontomys, which irrupted on the burned grass area during the second recovery year. The change in habitat type from brush to grass was accompanied by a general species shift from brush dwelling mice to grass dwelling species.

Sampson (1944). Fire destroys many small mammals, notably brush and tree dwellers, or they may die later from starvation. Destruction by fire of small surface-dwelling mammals, on the other hand, is mostly temporary; frequently, because of the increased food supply, mice and squirrels soon increase in numbers in excess of those present before burning. Because of their mobility, coyotes and certain other large predators are little affected by fires of ordinary size. Deer are seldom injured by small fires, but extensive burns have sometimes resulted in their starvation, injury, or death. Small openings may appreciably increase the forage for deer, but larger burns destroy the protective cover and temporarily deplete the food supply. Extensive brush fires are also adverse to bird life, whereas small, judiciously placed spot fires may be beneficial by providing secluded feeding areas adjoining the unburned cover.

Shantz (1947). With regard to wildlife, fire of the spot variety has benefited wildlife of certain types, especially deer, quail and turkey. Small fires with edge effects and fire breaks are favorite feeding grounds. But large broadcast fires might either destroy outright or starve seriously many types of game including deer, quail and turkey, as well as most of the other wildlife forms except mice and ants and probably the larger predators. By changing mixed types of vegetation to chamise, whole areas are made unfavorable for deer and other wildlife, and such is the tendency in most of the brush ranges.

Sumner (1931). The restricted burning policy for brush areas apparently has had an unfavorable influence upon quail in some foothill regions. The chief food items for quail have been largely choked out.

Storer (1932). The policy of forestry officials in restricting burning on forest and chaparral areas became a deer problem. Fire was a common and repeated occurrence in earlier years. There were numerous small fires, there being less accumulation of fuel. The chaparral was more open but became impenetrable with reduced burning. Herbaceous vegetation became scarce.

Horne (1938). On a thousand acre burn, deer avoided the fire and returned the first year, rabbits were eliminated for several years. Chipmunks were reduced to a breeding nucleus. Mice survived the fire in good numbers.

Hanes (1971). The slowest succession in south-coastal chaparral is on lower south slopes. Climax vegetation develops within 30 years after fire. Chaparral succession is not a series of vegetational replacements, but a gradual ascendance of long-lived species present in the pre-fire stand. Maintenance of vigorous chamise-chaparral is dependent upon fire. The fire exclusion policy is least apt to perpetuate chamise-chaparral.

Corbett and Rice (1966). In the San Dimas area, six years after about 350 acres of a burned brushland was converted to grass, the area and number of soil slips were about five times greater on the grass area than on the naturally recovering brush cover.

Hendricks (1968). In Lake County, ideal deer range could be made up of many 5-10 acre burns scattered through an entire area. This is not feasible due to excessive cost. Intermediate-size burns of 100-200 acres are practical. Most brush began sprouting within a few weeks after burning. Grass growth was much improved. Deer left croplands to return to burned hillsides where food was abundant. Old brushfields produce about 50 pounds of available feed per acre with a protein content of about 1 percent. After burning, the same area may produce a ton of available forage at around 6 percent protein. Shrub sprouts should not be sprayed with herbicide for optimum deer populations. For deer range, burn every 10 to 12 years; for livestock (grass production) burn every 3 or 4 years for awhile. Size of burns can be too small, resulting in overuse. Control burns also improve habitat for quail, doves and rabbits.

WOODLAND
Oak woodland - Bushland

Kittams (1972). New Mexico. In the evergreen shrub type, burning improves deer forage. Shrubby redberry juniper (J. pinchoti) and alligator juniper (J. deppeana), skunkbush (Rhus trilobata) and hairy mountain mahogany (Ceanothus breviflorus) all sprout following fire, and are preferred deer food. Oaks, at higher elevations, are improved by burning. Ceanothus greggii, much used by deer and often decadent, rarely sprouts, but fire results in seedling production. Among other plants sustaining more use following fire are: catclaw, sacahuista, goldeneye and dalea. Range recovery may take from 5 to 10 years for species like skunkbush, up to 50 years for juniper.

Baldwin (1968) Arizona. Grazing capacity in chaparral is low for both wildlife and livestock because of the impenetrable cover and limited herbaceous growth. It appears that burning and spray treatment have improved the habitat for white-tailed and mule deer. Increases in the quail population were noted, and a notable increase in songbird populations was noted in the spring.

WOODLAND
Pinyon - Juniper

Arnold et al. (1964). In Arizona, pinyon and juniper have invaded both grazed and ungrazed grasslands. Small-scale broadcast burning of live stands of pinyon-juniper under controlled conditions was tried. Most of the type was too open for fire to carry between trees. Removal of over-story trees resulted in release of small trees, shrubs and grasses. A light layer of slash increased production of grasses and forbs nearly 100 pounds per acre in one year. An August burn removed the most slash and killed the most trees that had been missed on cabled areas. Burning increased grass production. If protected from fire, both shrub and grassland will be reinvaded by pinyon-juniper. Burning grasslands killed trees up to 3 feet in height. Grazing must be withheld prior to burning so fuel will be present. There is a high demand for forage and a low demand for trees in the area. Suppression of palatable understory browse and herbaceous species by overstory evergreens has reduced the forage supply for both game and livestock.

McCulloch (1969) Arizona. An extensive crown fire burned pinyon-juniper-sagebrush type in the Grand Canyon plateau region. Burned areas were devoid of living trees. Thirteen-fifteen years after the fire, woody cover consisted of numerous dead trees, sparsely scattered clumps of sagebrush and rabbit-brush, and Gambel oak (8-10 ft. tall). There were also dense stands of seeded grasses. Deer intensively occupied both burned and unburned areas during summer, and the first fall-winter period. During a severe winter, pellet accumulation rate was appreciably greater on the burn. Rates were high in the burned zone up to 1/2 mile from live woodland. Green grasses were probably important deer foods on both the burn and non-burn in all seasons. Deer abandoned the burn for brief periods when snow was deep. Forbs and grasses were more abundant on the burn; browse forage-plants were more abundant on unburned woodland. Small burns would seem desirable if the area were to be managed only for deer because of the greater variety of cover and food than on large areas either burned or unburned. Livestock managers desire large blocks for treatment.

DESERT
Cold

Klebenow (1972). Fire seemingly can be an ideal tool to achieve our management objective, a diverse habitat providing for all the needs of the sage grouse. In Idaho, an area unintentionally burned created a strutting ground that birds were quick to occupy. These openings are necessary for the birds, and small burned areas, 1 to 10 acres in size, at the elevations utilized for breeding would be beneficial in homogeneous sagebrush types. Where sage is dense, habitat improvements could be achieved by moderate burning coupled with grazing management to get the desired mosaic of shrub grass and forbs. Repeated burning could be bad in this case, as could the use of large, hot fires where an excessive amount of cover is removed. Where cover is limiting, burning has been a problem. Fire can be an important part of management of meadows invaded by sagebrush. Small areas burned to produce a mosaic of food and cover should be desirable. There should be different stages of successional growth to produce the greatest variety of forbs. Rotational burning of different patches each year or every few years, possibly with as long as 20 years between burning treatments was recommended. Fire appears to be an ideal tool to create openings and a diversity of habitat types. Blaisdell (1953) reported considerable higher yields of forbs on burned sites. In wintering habitats, there seems to be little place for fire due to complete reliability on shrubs for food or cover. Burning should be a more desirable practice than the present reliance on herbicides. In Nevada, the Forest Service has burned portions of ranges with the objective of increasing habitat diversity for all occupants. In one case 650 acres was burned in April in small patches (1 to 20 acres) within a 4,000 acre pasture. The low-intensity fires had little effect on grass and forbs. Fire is a natural force to which organisms have adapted. Treatment cost is lower for fire, even on small scattered tracts, than for other treatments such as herbicides.

Christensen (1970) Nevada. When cheatgrass fires occur after chukars are capable of strong flight, it is doubtful that any serious loss is sustained. Chukars have been observed to return to a burned area almost immediately following a fire.

DESERT

Hot

Cable (1972). Shrubs are most susceptible to burning in June. Mature mesquite and creosotebush can be controlled by burning if sufficient ground fuel is present. False mesquite and some other species sprout. Fire can be used to control spread of shrubs. Prescribed burning seldom increases perennial grasses in the southwest semi-desert.

Soutiere and Bolen (1972). A cool spring fire produced little effect on mesquite trees or their use as mourning dove nesting sites. Doves nested on the ground when trees were killed (herbicide). Current year burns made better ground-nesting habitat than did older burns except during drought. Density of nests decreased each year after the fire. Fewest nests were in the unburned area. Ground-nesting doves prefer open cover. Fire preceding a drought year is disastrous to dove nesting.

Humphrey (1963). Fires have not been much of a factor historically in the Sonoran or Chihuahuan deserts. In desert grassland, fires formerly occurred at frequent intervals; mesquite and other woody species have invaded with fire control. Where fuel supply is adequate, controlled burning could still be used on the grasslands.

SOUTH - SOUTHEAST

Stoddard (1931). The bobwhite of the southeast undoubtedly evolved in an environment that was always subject to occasional burning. Large portions of the quail preserves of the region have burned over annually for a long time. Fire may well be the most important single factor in determining what animal and plant life will thrive in many areas. Uncontrolled burning in forests causes vast losses in forest products. Unburned, abandoned fields grow up to dense cover, but there is a reduction of seed-bearing weeds, also quail predator numbers increase. Such areas frequently burn, the hot fire consuming most vegetation, and they become unproductive. Dense, rough vegetation areas are avoided by quail. Winter burning will prevent formation of these dense mats. Uncontrolled burning at all seasons on these lands has done great damage to quail. Summer fires may produce ground cover of the right density but they greatly reduce the food supply and many nests are destroyed. Annual burning is never desirable over extensive areas of quail lands because of its injury to the fruit supply. It is a calamity when ground cover burns during the nesting season. February burning, after seeds have matured and fallen, and before new growth starts, by fires of the creeping type, stimulates legumes. Burning also makes the shattered seed available to birds, whereas it is not available if under a mat of litter. Fires in March, after growth starts and early (turkey) nesting begins, are harmful. Fire is useful in removing cover in swamps and other low areas which usually flood and destroy nests. Berry vines and fruiting shrubs produce little fruit the first year when it is renewing top growth. Fire may aid in the control of certain quail diseases and parasites. Fire lanes provide openings used by birds; also good feeding areas.

Conclusions

1. Dual use. Quail and timber can be raised on the same property (though usually not maximum crops of either).
2. Use of fire is justified to control vegetation of jungle-like growth, if fire is carefully controlled.
3. Burning in winter and at night with a creeping-type fire, in alternate years or as needed, may increase food supply, regulate density and extent of ground cover, aid in nest distribution, and aid in control of disease and parasites.
4. Uncontrolled use of fire is condemned. Fire should be used only under close supervision.

Stoddard (1963). Most marsh areas may be burned during fall, winter, or early spring to benefit waterfowl. This also reduces risk of wild fires during nesting season of resident birds. Summer fires damage bird nests and young. Seed and fruit crops of the year are reduced. Southeastern pine forests protected from fire become overgrown with understory brush of little value to birds. Over a long period, pine converts to hardwood. The hardwood is better bird habitat than overgrown pine - more for turkey, less for quail. Quail and turkeys are attracted to burning pines - pine seed, insects, and other food becomes available. Hawks are attracted during a fire. Small birds which are attracted include robins, bluebirds, doves, sparrows, and woodpeckers. There should be well-distributed small areas not burned frequently, for production of fruit-bearing shrubs. Few animals are found killed in fresh burns.

Komarek, E. (1971). Fire is essential in the management of wildlife and range animals, and plants in the southeastern pine forest, grasslands, and adjacent wetlands. Ecologically, fire has been a natural force affecting these communities long before man arrived. All living things respond to certain biological laws, and the relationship of fire to these laws must be recognized and understood. Emphasis must be on the habitat rather than on the wildlife. In the southeast, under a pine-quail management program where controlled burning is regularly conducted, fine quail hunting has been developed to the point where 30 to 35 coveys per shooting day can be found with regularity throughout the season. In some regions, on good soils, the undesired successional change can occur so rapidly that the grassland and its inhabitants can be replaced in from 3 to 6 years of fire exclusion. Through burning, these grasslands under the pine are kept in a youthful stage of plant succession productive of wildlife. Fire, when properly applied, favors grasslands over bush or forest. When a burn greens up with new vegetation, it has a very strong attraction for many species of animals - including high populations of insects. The disappearance of the heath hen is a good example of species elimination through fire exclusion.

Komarek, E. (1969). Many animals require fire to condition the habitat in which they live. For example, annual fires are a virtual necessity in the management of high populations of bobwhite quail in parts of the southeast. Animal response to fire may be: avoidance, attraction, response to blackened areas, or response to greening areas. Examples of avoidance are rabbits, large mammals, and rattlesnakes. Predatory birds and vultures sometimes are attracted to smoke or fire; also, some insects. Some species are attracted to fresh, black burns; examples include predatory species. Bobwhites will scratch and feed in a burn still smoking. Animals such as the varying hare and white-tailed deer seem to ingest ash or charcoal. Many herbivores are attracted to new green growth following fire.

Blakey (1947). Exclusion of natural and planned burning in some forests (Texas) has resulted in a jungle of mixed hardwoods that definitely limits the carrying capacity for wildlife. In the absence of burning on the Aransas Refuge, the succession goes directly to brush dominated by live oak. The brush is becoming so dense it will exclude or limit use by most wildlife species. A combination of cutting and burning has been used for opening the cover initially. Thereafter, burning at frequent intervals maintains the desired conditions. Grass is the medium necessary for carrying a controlled fire. Proper burning does not kill the stand of perennials. Some of the most valuable forage and wildlife food plants are stimulated by the burning process. Some of the most valuable grasses appear most abundantly immediately after burning. It is doubtful that a rich leguminous flora can be retained for long without some amount of burning. Brush will overtop the grasses within five years if burning is not repeated. Live oak cannot survive properly planned and executed burning. Wildlife species benefited include: deer, turkeys, quail, dove, jacksnipe and sandhill cranes. Some wintering song and insectivorous birds must readjust to unburned tracts. Predators find less protection.

Miller (1963). With only minor exceptions, upland wildlife has a marked affinity for subclimax plant associations. This indicates that disturbance has been a common occurrence through evolutionary time. For wildlife species to be perpetuated, the particular subclimax vegetation which is their natural habitat, must be maintained. Cover conditions for prairie chickens are best where woody cover does not exceed 25 percent; they require grassland (height and density are the important factors). Sharptails prefer less than 40 percent woody cover (semi-prairie); the woody cover should be in scattered small groups rather than evenly distributed. Controlled fire will maintain these conditions. Ruffed grouse require small brushy openings (about 1/4 acre), well dispersed. Turkeys need larger grass-forb openings of 2 to 3 acres in mature timber with an open understory. Kirtland's warbler in Michigan jack pine has habitat requirements produced only by forest fires. Burning also improves food conditions for prairie chicken, sharp-tail grouse, bobwhite quail, turkey, and white-tailed deer.

DeWitt and Derby (1955). Maryland. A plot study to determine nutritive value of several deer browse-forage species showed that four species were unaffected by fire. Protein content was significantly higher in greenbrier (*Smilax*), red maple and dogwood foliage in the season following low-intensity fire, but no effects were found the second year. The high intensity fire produced significant increases in protein contents of all four species (as above, plus white oak), and effects were still apparent at the end of two years.

Baker (1973). Of 66 pine trees that died following lightning strikes, all showed use by woodpeckers feeding; 80 percent had holes suitable for nesting or roosting. Hawks and vultures use snags for perching. Smaller birds, as chickadee and nuthatch, nest in snag cavities. Bats roosted under loose bark. Small mammals, as rodents, utilize burned out root systems. Bears den in large holes. Burned out bases and root systems may be used by various reptiles. Numerous arthropods utilize dead trees under the basal bark. A number of forms of wildlife are associated with dead snags. Some species may be more or less dependent on dead trees.

Cushwa and Martin (1969). The southeastern Coastal Plain is a fire-disturbed ecosystem. The flora and fauna have evolved in the presence of frequent burning. The characteristics of a fire that determine the effects on the biotic community are: (a) fire temperatures, (b) duration of temperature, and (c) transfer of heat. These factors are governed primarily by (1) fuel size, moisture content, and density; (2) fuel arrangement and (3) wind. Also, note heat transfer within a body and the lethal temperature-time relationships of living tissue.

Zontek (1966). On a southeastern marsh (refuge) for waterfowl, prescribed burning is an important management tool. With early, improved fire protection, a decided decrease in the upland game populations and in waterfowl use of the marshes became apparent. In the winter of 1940-41, 120 acres of marsh were experimentally burned and good use by geese was made of the new growth. Burning has been continued over a 25-year period. Burning is on a 3-year rotation. Geese prefer burned marshes. Burning followed by flooding is used to retard or control pest plants in fresh and brackish-water marshes. After prescribed burning practices were initiated, a noted increase in the turkey population was observed. The deer population appears to be increasing. Prescribed burning's principal accomplishments for wildlife are: 1) Reduces wildfire hazard; 2) reduces the dense ground growth of perennial grasses and shrubs, leaving conditions suitable for legumes and annual weeds to become established; 3) removes small understory pines and hardwoods that are of little value.

Perkins (1968). In Louisiana, fire plays a most important role in marsh management for muskrats. Ninety percent of their forage species must be burned at least every other year to maintain itself. Wildfires directly destroy many muskrats. Winter food of the blue goose can be improved by burning. Fall burning is recommended. Without annual burns neither normal nor peak muskrat populations can be reached.

Sharp (1970). In Pennsylvania, wildlife management in the absence of controlled or prescribed burning creates only temporary or short term benefits to ruffed grouse. Normally one grouse per 10 or more acres is a reasonable population while units under fire management will carry one bird per 2 to 4 acres. The ruffed grouse appears to be a fire climax species or one that benefits from recurring fires in its habitat. Its key food plants are fire induced at crucial stages of development such as by stimulating seed germination and seedling establishment, by rejuvenating decadent plants, or by controlling plant disease. Fire retards or delays encroachment of the closed canopy forest. The grouse populations are found on areas having a history of recurring fires. Nests, on the ground are placed in areas of little cover. Fire prior to egg laying would not affect quality of nesting cover. Later, fire would destroy clutches. Spring burns attract adults and later, broods.

Gullion (1974) Minnesota. While occasional losses of wildlife do occur, most species benefit much more than they suffer when fire sweeps a forested area. Fire in the forest is the ecological agent most likely to maintain habitat qualities beneficial to bears. The habitat requirements of other forest wildlife species show similar associations between the disturbance created by fire in the forest and the abundance of many animals. There is good evidence that many grouse are dependent on fire. The prairie chicken evidently thrives best on grasslands which are burned at nearly yearly intervals. There is increasing evidence that an important reason for the decline in sharp-tail grouse in the midwest is the elimination of fire in the meadows and bog areas adjacent to forest - although conversion of brush to cropland has been an important factor. Intensive research in the Lake States has indicated that fire provides the highest quality habitat for ruffed grouse. Windthrown or "cleared" forest followed by fire provides quality habitat for a period of about 40 years. Fire also produces quality habitat for white-tailed deer. There is good reason to suspect that the success of fire prevention programs is the major factor responsible for the continent-wide decline in deer numbers. This affects a remnant wolf population. Fire also is related to habitat of moose, beaver and snowshoe rabbit. Food of desert quail is more abundant on burned rangelands than on unburned chaparral or blackbrush. For ruffed grouse, fires at about 8 to 12 year intervals and 1 to 3 acres in size, are most desirable. A mosaic of mixed age classes is needed. Fire patches larger than 10 to 12 acres have adverse effects. Deer benefit from burns of 30 or 40 or up to 100 acres. For moose, fire must be 2 to 10 times that large for greatest benefit. While wildfire is generally unacceptable in wildlife management, prescribed fire is a useful tool. Once a hardwood forest has aged beyond 50-60 yrs., habitat restoration requires felling the timber before burning.

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